AUTOMATIC DETECTION OF RANGE VARIANCE OF FACADES FROM VEHICLE-BASED IMAGE SEQUENCE

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ABSTRACT:

Vehicle-based image sequence is taken on a moving vehicle, therefore, all scenes passed by will be included, e.g. buildings, cross-road etc.. Images including cross-road are obviously useless for building facade texture. Therefore, those images should be excluded from processing. In this paper, subsection of image sequence is implemented according to range variance automatically detected by the histogram of projective difference of corresponding points. Firstly, projective difference of corresponding points on common projective plane is calculated according to the DC parameters determined. As far as corresponding points on facade be concerned, the projective difference should be very small or even ideal zero. Corresponding points in cross-road or on other facades having obviously range variance with common projective plane, however, have large projective difference. Accordingly 1-D histogram along *x*-axis of image coordinate system is drawn to show the distribution of projective difference. Experiments show that cross-road and facades having large range variance are represented in the histogram by peak areas. Moreover, the 1-D locations of peak areas in the histogram are obviously corresponding to those having large range variance. By histogram of corresponding points, therefore, not only the existence of range variance is detected, but also the location of range variance in image is indicated because it is drawn following the moving direction of vehicle. According to the location indicated, images including cross-road are excluded from image sequence and subsections of image sequence are divided for facades having large variance with each other as well.

1. INTRODUCTION

Since the street is a primary component of city, it is very significant for 3D city modeling (3DCM) that how to rapidly realize the 3D visualization of street sight. The acquisition of vehicle-based image sequence for buildings has the characteristics of convenience and rapidness. Moreover, the resolution of textures obtained from vehicle-based image sequence is very high. Therefore, it will be aided greatly by the automatic processing of textures from vehicle-based image sequence that the 3D visualization of street sight in 3DCM. [1]

Vehicle-based image sequence is taken on a moving vehicle, therefore, all scenes passed by will be included, e.g. buildings, cross-road etc.. To improve the efficiency of processing building facade texture from image sequence, the image segments covering building facade should be automatically corresponded to each building. Moreover, images including cross-road are obviously useless for building facade texture. Therefore, those images should be excluded from processing. Since the camera is active while the buildings are static, tracking building facade in the image sequence is similar to track moving object while camera is static. Motion tracking is one of the most important issues in computer vision. In case of using a static camera, background estimation is a popular method for detecting foreground objects. There are many researches of background estimation (Karmann et al., 1990; Harwood et al., 2000; Javed et al., 2002; Koller et al., 1994; Mittal et al., 2004). As we know, it is highly difficult to detect moving objects from image sequences obtained by a moving camera since there exists the apparent motion of a static background. A number of methods of motion detection from a moving camera have been proposed (Rahman et al., 2004; Barcelo et al.,2002; Pan et al., 2000; Saptharishi et al., 2000); some are based on direct detection of camera parameters with sensors, optical flow estimation (Fleet et al., 1994) and registering the static background using a geometric transformation. Geometric transformation based methods are promising for real-time processing because of their low computational costs.

The building facades along the street are usually connected or contiguous in the same block. If the range difference between each facade is small enough, it is reasonable to regard them as a whole facade. Otherwise, subsection of image sequence for different facade should be divided respectively. Therefore, range difference can be used to track building facade. In this paper, range variance is automatically detected by the histogram of projective difference of corresponding points. Firstly, we calculate projective difference of corresponding points on common projective plane according to the DC parameters determined. Peak areas are then detected in the histogram to

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show the location of large range variance. According to the location indicated, images including cross-road are excluded from image sequence and subsections of image sequence are divided for facades having large variance with each other as well.

2. DETECTION OF RANGE VARIANCE

In this paper, the histogram of projective difference of corresponding points is used for automatic detection of range variance.

As Fig.1, the origin of the coordinate system chosen in this paper is the projective center S_1 of the first image. In general, most of building facades have a main plane, accordingly we choose the plane XY parallel to the main plane of facade. The ideal image plane P_0 of the first image (the distance between point S_1 and P_0 is focus f) is considered as public projective plane which is parallel to main facade plane and plane XY as well. As far as corresponding point on the facade a_1 and a_1' be concerned, the projective difference between their projection point A_1 and A_1' should be very small or even ideal zero. However, projection point A_2 and A_2' of corresponding point a_2 and a_2' not on the facade have large projective difference (Fig.1).

Firstly, the formula, describing the projective relationship illustrated as Fig. 1, is deduced as below based on the projective formula of image point on the projective plane.

$$\left.\begin{aligned} -(f+Z_{S1})\frac{a_{11}x_1+a_{12}y_1-a_{13}f}{c_{11}x_1+c_{12}y_1-c_{13}f}+X_{S1} &= -(f+Z_{S2})\frac{a_{21}x_2+a_{22}y_2-a_{23}f}{c_{21}x_2+c_{22}y_2-c_{23}f}+X_{S2} \\ -(f+Z_{S1})\frac{b_{11}x_1+b_{12}y_1-b_{13}f}{c_{11}x_1+c_{12}y_1-c_{13}f}+Y_{S1} &= -(f+Z_{S2})\frac{b_{21}x_2+b_{22}y_2-b_{23}f}{c_{21}x_2+c_{22}y_2-c_{23}f}+Y_{S2} \end{aligned}\right\} \quad (1)$$

Where, f : Focal length

(X_{Si}, Y_{Si}, Z_{Si}): the coordinate of projective center S_i

$\begin{bmatrix} a_{i1} & a_{i2} & a_{i3} \\ b_{i1} & b_{i2} & b_{i3} \\ c_{i1} & c_{i2} & c_{i3} \end{bmatrix}$: the rotation matrix of image p_i

(x_i, y_i): the coordinate of image point a_i（$i = 1,2$）.

$$\left.\begin{aligned} \Delta X &= -(f+Z_{S1})\frac{a_{11}x_1+a_{12}y_1-a_{13}f}{c_{11}x_1+c_{12}y_1-c_{13}f}+X_{S1}+(f+Z_{S2})\frac{a_{21}x_2+a_{22}y_2-a_{23}f}{c_{21}x_2+c_{22}y_2-c_{23}f}-X_{S2} \\ \Delta Y &= -(f+Z_{S1})\frac{b_{11}x_1+b_{12}y_1-b_{13}f}{c_{11}x_1+c_{12}y_1-c_{13}f}+Y_{S1}+(f+Z_{S2})\frac{b_{21}x_2+b_{22}y_2-b_{23}f}{c_{21}x_2+c_{22}y_2-c_{23}f}-Y_{S2} \end{aligned}\right\} \quad (2)$$

To calculate the coordinate difference between correspondingly projective points, Eqs.1 is transform to Eqs.2.

Accordingly 1-D histogram along x-axis of image coordinate system is drawn to show the distribution of projective difference (Fig.2). The corresponding points are sorted by x coordinate so that the distribution of those points in the histogram corresponds to that in the image. In the histogram, the sequence number of corresponding point is along the x-axis and the projective difference is along the y-axis. In Fig. 2 , every corresponding point pair has projective difference owing to the corresponding point matching and orientation parameter errors. Therefore, we implement filtering to make the detection of peak areas straightforward in the histogram. By comparing Fig.2 and 3, we can see that cross-road and facades having large

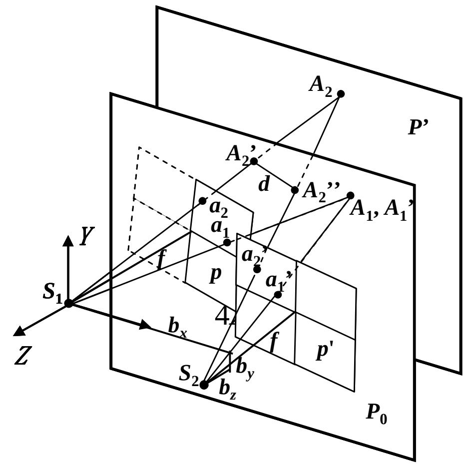

Fig. 1 The projective geometry of corresponding points

range variance are represented in the histogram by peak areas. Moreover, the location of range variance in the image is indicated by the location of corresponding peak area in the histogram because the histogram is drawn following the moving direction of vehicle. According to the location indicated, we can decide from which image the building facade appear and disappear after which image. As a result, images including cross-road are excluded from image sequence and image sequence are divided into segments among which each segment is corresponding to a building facade.

3. EXPERIMENTS

Experiment was implemented on automatic image sequence subsection using the method presented in Section 2. As shown in Fig.4 a 146 meters long segment of street facade consists of two cross-roads and four connected buildings. There are 58

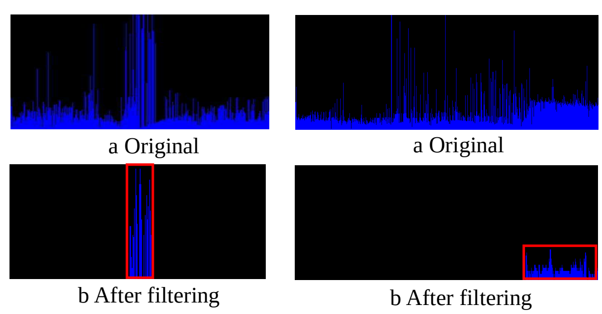

Fig. 2 The histogram of projective difference of corresponding points

a. Cross-road

b. Connected buildings with large range variance

Fig.3 Segments with large range variance

Fig.4 Vector map

images taken to cover this segment. The histograms of projective difference of corresponding points (Fig.5) were generated to indicate the position of large range variance from those images. In Fig.5, the positions of peak values exactly indicate the positions in the raw images (Fig.6) of two cross-roads and the building (highlighted in a red rectangle in Fig.4) which has large range difference with others.

According to the position detected, the image sequence of 58 images was divided into two image segments and automatically corresponded to the buildings of interest because images were taken along the street in sequence.

4. CONCLUSIONS

In this paper, an algorithm was presented to automatically detect range variance by the histogram of projective difference of corresponding points. Since the building facades along the street are usually connected or contiguous in the same block, large range variance is only possibly detected at crossroads and connecting parts between two buildings which have large range variance. Large range variance is accordingly used to separate different building facade. As a result, building facade can be track from image sequence by range variance detection. Experiments show that cross-road and facades having large range variance are represented in the histogram of projective difference of corresponding points by peak areas. Moreover, the

a Cross-road *A* *b* Connected building *c* Cross-road *B*

Fig.24 Large range variance in raw images

1-D locations of peak areas in the histogram are obviously corresponding to those having large range variance. By histogram of corresponding points, therefore, not only the existence of range variance is detected, but also the location of range variance in image is indicated. According to the location indicated, images including cross-road are excluded from image sequence and subsections of image sequence are divided for different facades as well.

Furthermore, 1-D histogram can be extended to 2-D one by which the foreground (e.g. passersby, line trees etc.) are detected from the background (building facades). This process should be propitious to future texture analysis.

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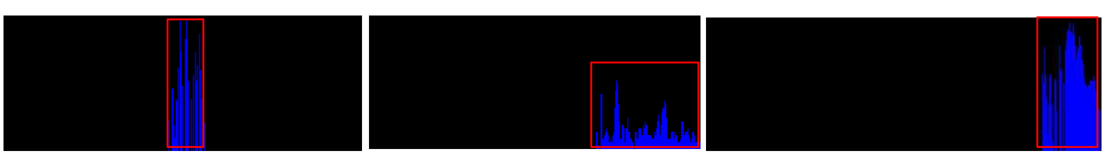

a Cross-road *A* *b* Connected building *c* Cross-road *B*

Fig. 6 The histograms for experimental image sequence

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